

# **Toward the Development of Severe Weather Outlooks**

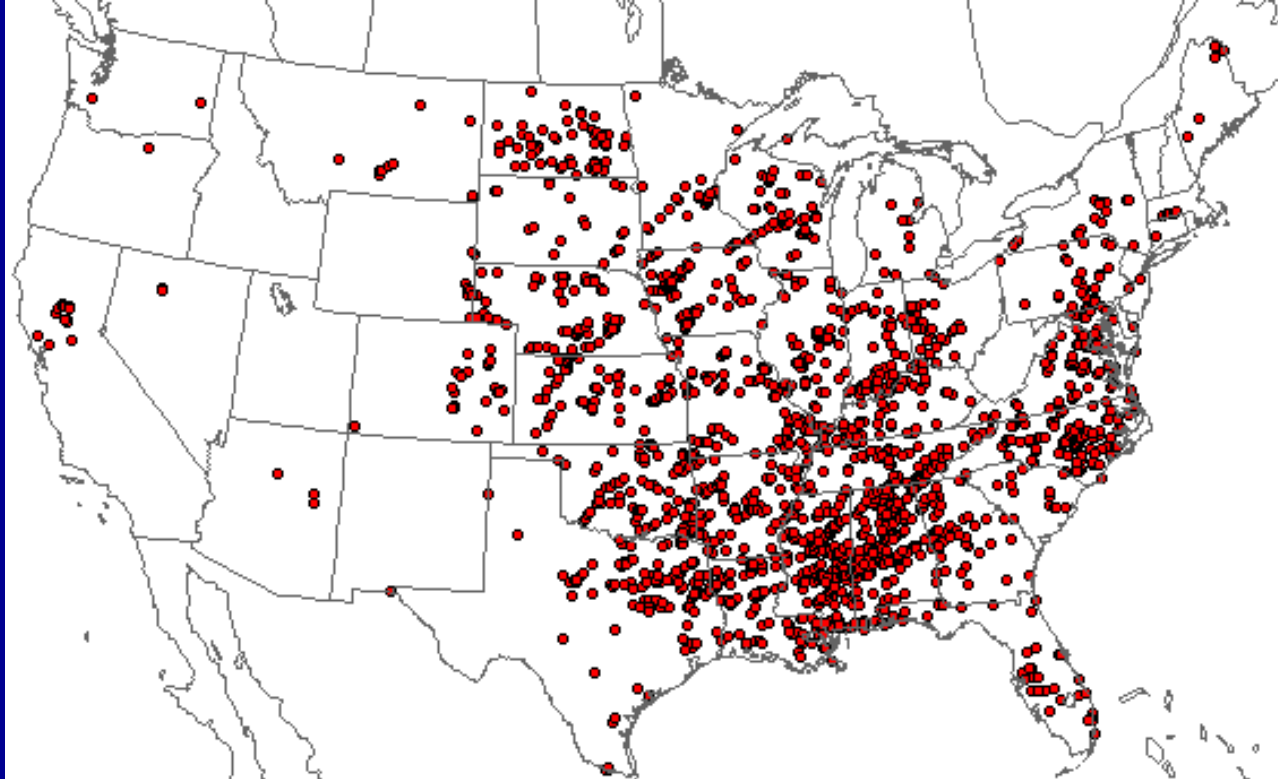
Scott Weaver  
NOAA Climate Prediction Center

2011 Tornadoes

6 "Events"

\$27.7 Billion

539 Fatalities



PRELIMINARY SEVERE WEATHER  
REPORT DATABASE (ROUGH LOG)

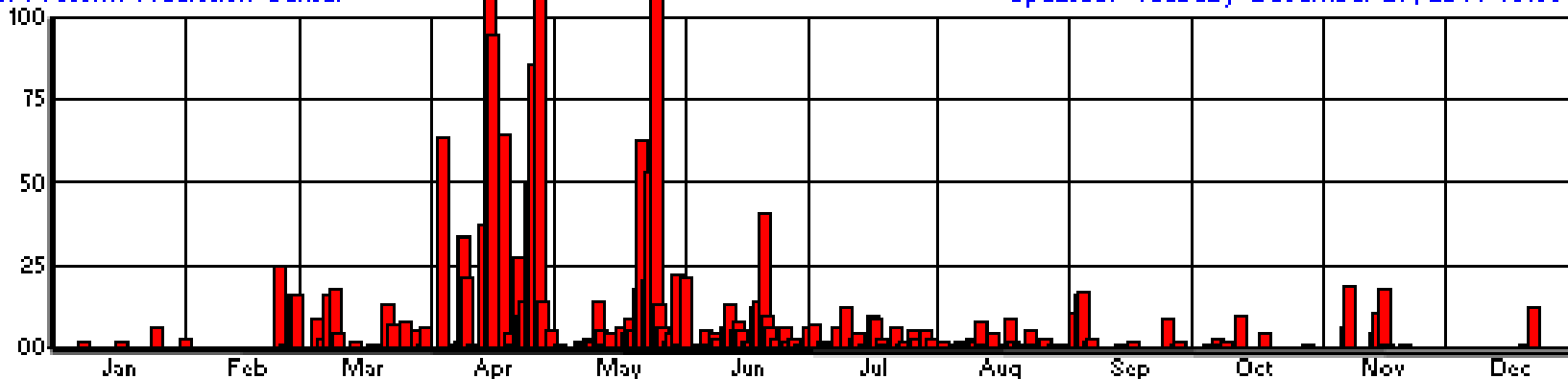
NOAA/Storm Prediction Center Norman, Oklahoma

Tornado Reports  
January 01, 2011 - December 27, 2011

Updated: Tuesday December 27, 2011 16:35 CT

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Tornado Reports

January 01, 2011 - December 27, 2011

# Community White Paper & NOAA Fact Sheet

## Advancing the Nation's capability to anticipate tornado and severe weather risk<sup>1</sup>

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forecast models; their ongoing work similarly demonstrates the viability of using global climate models, including the CFS, in such a dynamical downscaling approach. The forecast model – Weather Research and Forecasting (WRF) model – is configured such that convective clouds and storms are explicitly represented over the entire domain. The output of such convection-permitting WRF-model integrations over months and seasons is then mined to determine the spatial distribution and frequency of convective storms by type and severity. Figure 3 shows an example of a predicted severe storm occurrence over the period April through June of 2012, generated by WRF-enabled downscaling of the CFS model.

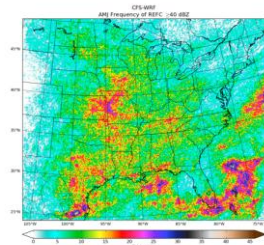


Fig 3. Example of predicted storm occurrence (simulated radar reflectivity > 40 dBZ) over the period April, May, Jun, 2012, generated by WRF-enabled downscaling of the CFS model.

## Observational Databases

Underpinning our current understanding of the severe weather environment and its climate connections is a long term (1950-present) historical database of F-scale tornado counts. Since this database was not intended to be a consistent homogenous long-term climate record of tornadic and severe weather parameters, there are inherent inconsistencies as a result of public awareness, tornado reporting practices, NWS guidelines, and other sources of inhomogeneity. These issues may introduce spurious trends in the long-term tornado data. However, it has been demonstrated that much of this trend can be ameliorated by focusing on the F1-F5 tornado counts only (Verbout et al. 2006) as demonstrated in Figure 4 which shows that much of the trend can be explained through the timeseries evolution of the F0 tornado counts. Nevertheless, it is necessary to explore other novel ways to further homogenize the long-term historical tornado database while simultaneously taking

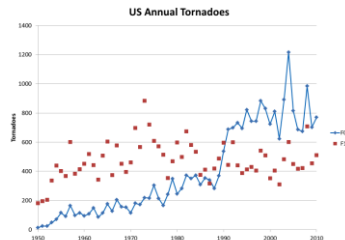


Fig 4. Time series of F0 (blue) and F1 and greater (red) annual tornado counts for 1950-2010.

## State of the Science FACT SHEET

### Tornadoes, Climate Variability, and Climate Change

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

This assessment of tornado activity and climate was developed by scientists and communication experts from the National Oceanic and Atmospheric Administration (NOAA).

Tornadoes are intense rotating vertical columns of air that pose a great threat to lives and property. They typically form in an environment where winds are rapidly changing direction and speed with height (commonly referred to as wind shear) and the atmosphere is convectively unstable. Tornado strength is classified according to the Fujita (F) Scale F0-F5, with F0 being the weakest and F5 the strongest<sup>2</sup>. Tornado activity refers to the number and intensity of tornadoes over a given region, season, or year. While tornadoes can occur during any season in the U.S., they are most likely during the spring months of March, April, and May.

Given the right set of atmospheric conditions, tornadoes can occur almost anywhere. However, the areas of the U.S. most susceptible include the Great Plains, Midwest and South. The configuration of the topography of the North American continent (Rocky Mountains, Great Plains, and proximity to the Gulf of Mexico) contributes to the development of large-scale weather systems capable of supporting severe thunderstorms and related tornado events.

### Are the frequency and/or intensity of tornadoes increasing?

Underpinning our current understanding of tornado activity is a long-term (1954-present) record of historical tornado counts from NOAA's Severe Weather Database (SWD). Given that the SWD was not intended to be a consistent homogenous long-term climate record of tornadoes, there are inconsistencies over time as a result of changes in public awareness, tornado reporting practices, Doppler radar technology, and National Weather Service (NWS) guidelines, to name a few.

These inconsistencies have likely introduced artificial trends in the long-term tornado data making attribution of long-term changes in tornado frequency/intensity difficult to determine. This issue is highlighted by a comparison of all tornado counts (F0-F5) with only the F1-F5 tornadoes (Figure 1). Removing the F0 counts from the database nearly eliminates the trend. Despite the potential for spurious trends in the SWD, this does not rule out the possibility that a portion of the trend is due to climate change or natural climate variability.

### What is the role of natural climate variability in tornadic activity?

Emerging evidence suggests that natural climate variations such as El Niño and La Niña events and in particular the transition from one to another in spring, have the potential to modulate the environmental factors

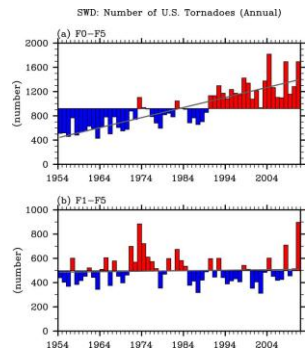


Figure 1. The number of F0-F5 (upper), F1-F5 (lower) annual tornado counts for 1954-2011 from the NOAA Severe Weather Database. The gray lines show the linear trend for the respective F-scale intervals. (From Lee et al. 2012)

conducive to tornado formation<sup>3</sup>. Natural variations acting on decadal timescales (e.g., Atlantic Multidecadal and Pacific Decadal Oscillations) have also been similarly implicated. However, uncertainty is higher because these phenomena are influential over the course of roughly 30 years and the tornado record is only approximately 60 years long. The link between these inter-annual-to-decadal natural climate variability modes and variations in tornado activity is typically via shifts in the large scale upper and lower level jet streams across North America that act as focusing mechanisms for severe thunderstorm development. Shifts in the placement and strength of these jet streams will influence the locations of

atmospheric instability and wind shear that promote enhanced or reduced tornado activity.

### Does climate change impact tornado activity?

Despite the existence of artificial trends in the SWD there is still a potential role for changes in tornado activity due to climate change. Given that tornado activity is dependent upon two things: the strength of atmospheric instability, which promotes rising air and thunderstorm formation; and vertical wind shear, which provides the necessary rotation for tornadic thunderstorms (Figure 2), the best approach is to assess the likely impact climate change will have on these proxy indicators. Nevertheless, this is not straightforward since early indications show a likely tug-of-war between these two mechanisms<sup>4</sup>.

In general, climate change is expected to increase atmospheric instability by increasing temperature and humidity in the lower atmosphere, while simultaneously weakening vertical wind shear through a reduction in the surface pole-to-equator temperature gradient. The result is regions that currently see the highest frequency of tornado activity may experience reductions due to weakened vertical wind shear, unless this is offset by the increases in atmospheric instability. Additionally, these factors could modify the seasons of tornado activity, i.e., enhance cool season activity. Some observations indicate storminess is increasing in general, suggesting atmospheric instability may be winning out over the wind shear influence.

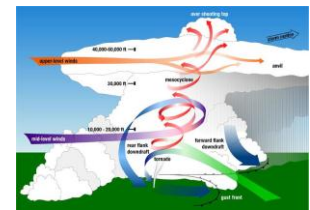


Figure 2. This schematic of a supercell thunderstorm shows how instability and wind shear influence tornado formation. The unstable rising air (red arrows) is forced to rotate by the increased wind speed between the lower (green) and mid-to-upper levels (purple-orange).

### Can we predict long-term changes in tornado activity?

Emerging evidence suggests it may be possible to provide prediction of overall tornadic activity over the U.S.<sup>5</sup> However, the viability of providing long-term (i.e., monthly and seasonal) outlooks of tornadoes has not yet reached a level necessary to provide actionable

information. Since current versions of climate models do not have the resolution necessary for explicitly representing the extremely small-scale tornadic structures, other techniques are being explored. The current strategy focuses on the prediction of local proxy indicators (atmospheric instability and wind shear) and remote climate signals (El Niño/La Niña transitions and other climate variability modes). An effort is underway to develop a quantitative monthly-to-seasonal prediction system that exploits new insights and knowledge as they are discovered.

The potential for predicting longer-term tornado activity (i.e., decadal-to-centennial) is much less clear given the inherent uncertainties in the model based prediction of decadal-to-centennial regional climate change. To be sure, there is much room for improvement and large gaps exist in current understanding on all timescales. However, it is widely believed among the scientific community there is great potential for research to fill these gaps.

### How should research be directed to improve understanding?

Near-term research should target several crucial areas:

- Improve understanding of the influence of large-scale natural climate variations on tornadic activity.
- Improve understanding of potential climate change impacts on the frequency and/or intensity of tornadoes.
- Advance modeling and downscaling strategies.
- Explore new ways to make better use of the historical database (i.e., focusing on tornado days, path length and width, etc.) and develop a modern record that exploits recent technological advances.
- Integrate societal needs into the research process to better align the applicability of research advances.

### Additional Resources

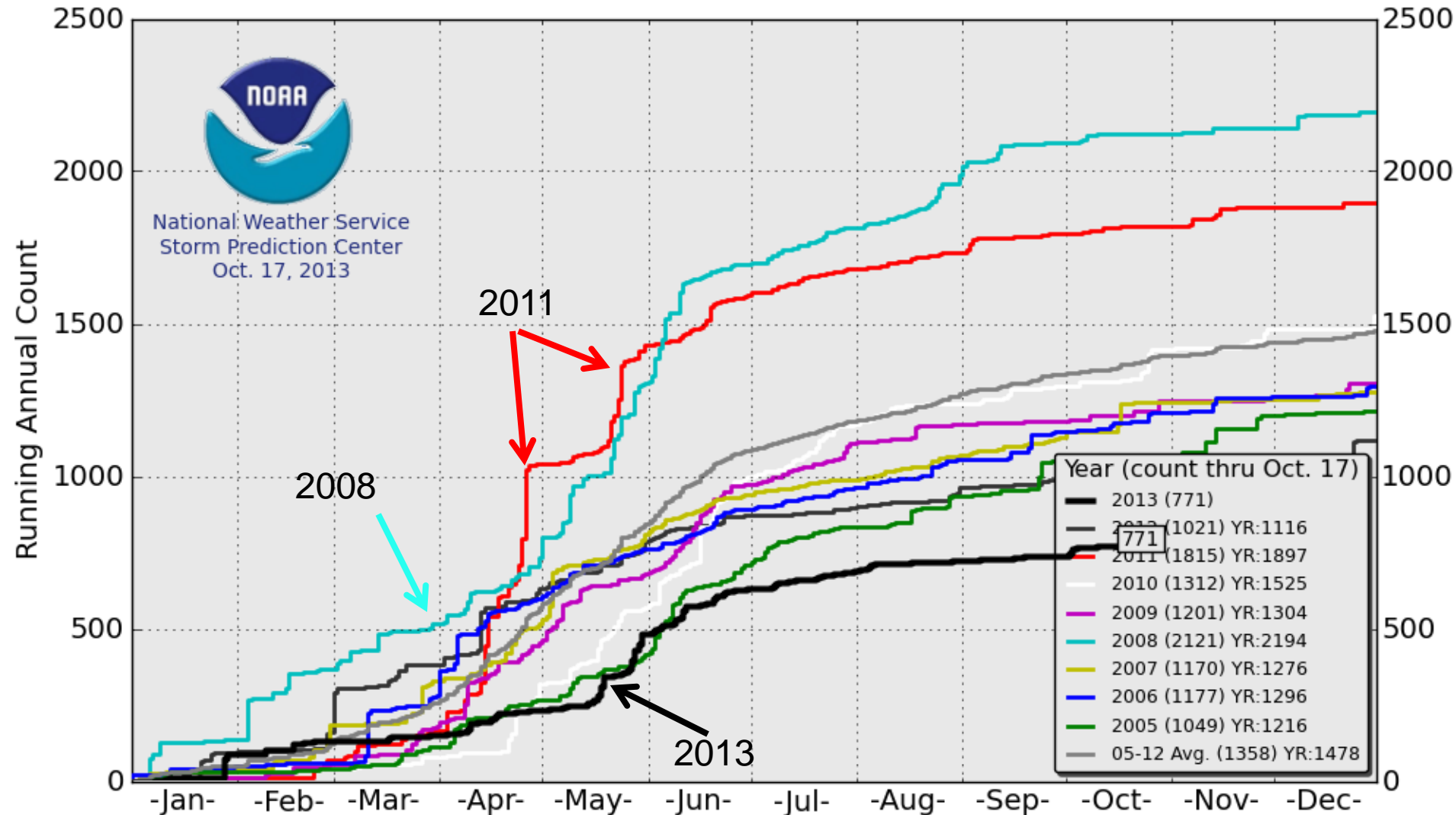
References:

- <sup>1</sup> Lee, S.-K., R. Atlas, D. Enfield, C. Wang, and H. Liu, 2012: Is there an optimal pattern that enhances large-scale atmospheric processes conducive to tornado outbreaks in the U.S.? *J. Climate*, **26**, 1626-1642.
- <sup>2</sup> Diffenbaugh, N. S., R. J. Trapp, and H. Brooks, 2008: Does global warming influence tornado activity? *EOS, Trans. Amer. Geophys. Union*, **89**, 53, doi:10.1029/2008EO530001.
- <sup>3</sup> Tippett, M. K., A. H. Sobel, and S. J. Camargo, 2012: Association of U.S. tornado occurrence with monthly environmental parameters. *Geophys. Res. Lett.*, **39**, L02801, doi:10.1029/2011GL050368.

\*A new Enhanced Fujita scale was adopted in 2007.

# Tornadoes 2005-13

United States Annual Trend of LSR Tornadoes\*



\*Preliminary tornadoes from NWS Local Storm Reports (LSRs)  
Annual average is based on preliminary LSRs, 2005-2012

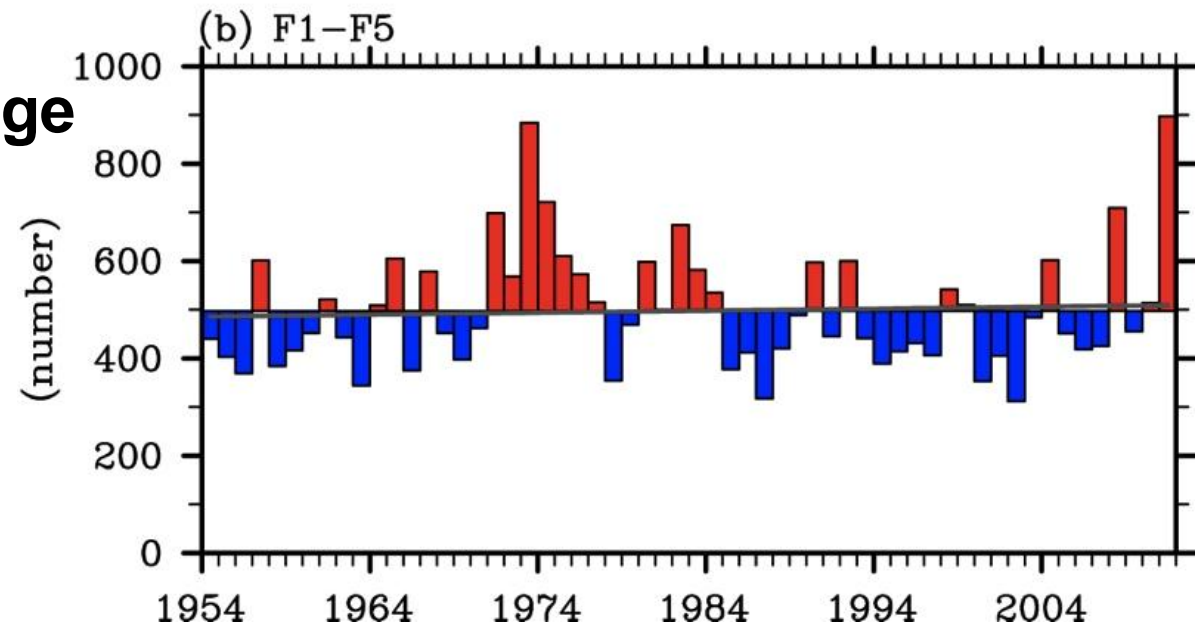
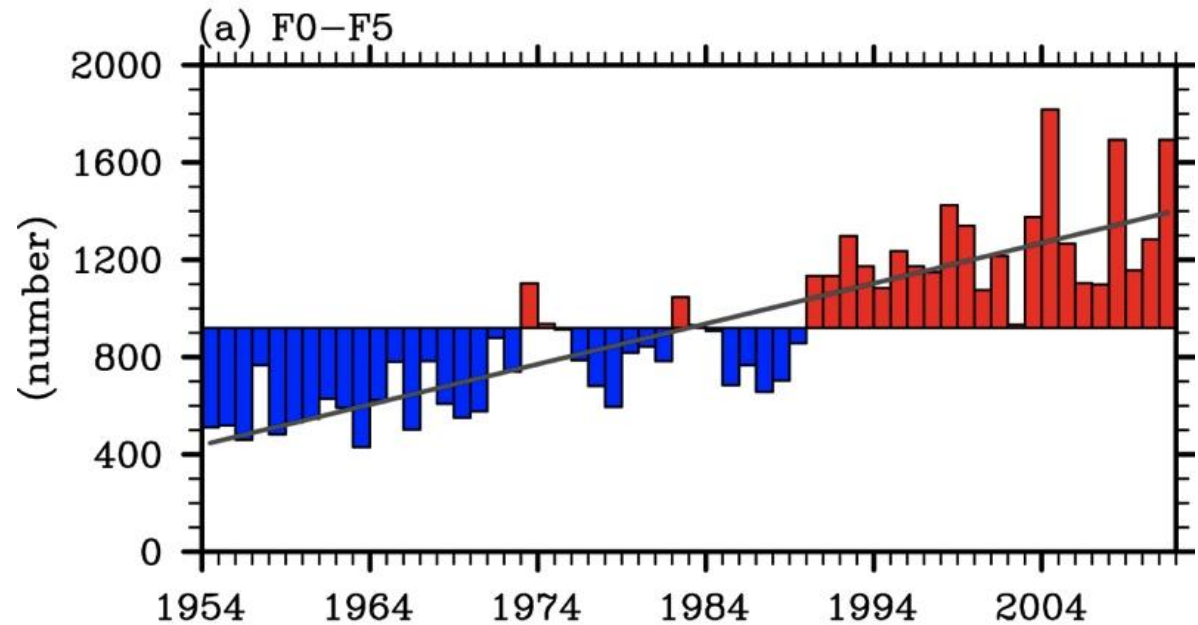
How can we improve understanding  
of long term changes and year-to-  
year variability?

## SWD: Number of U.S. Tornadoes (Annual)

**The Problem?**

**The Solution  
Use F1-F5?**

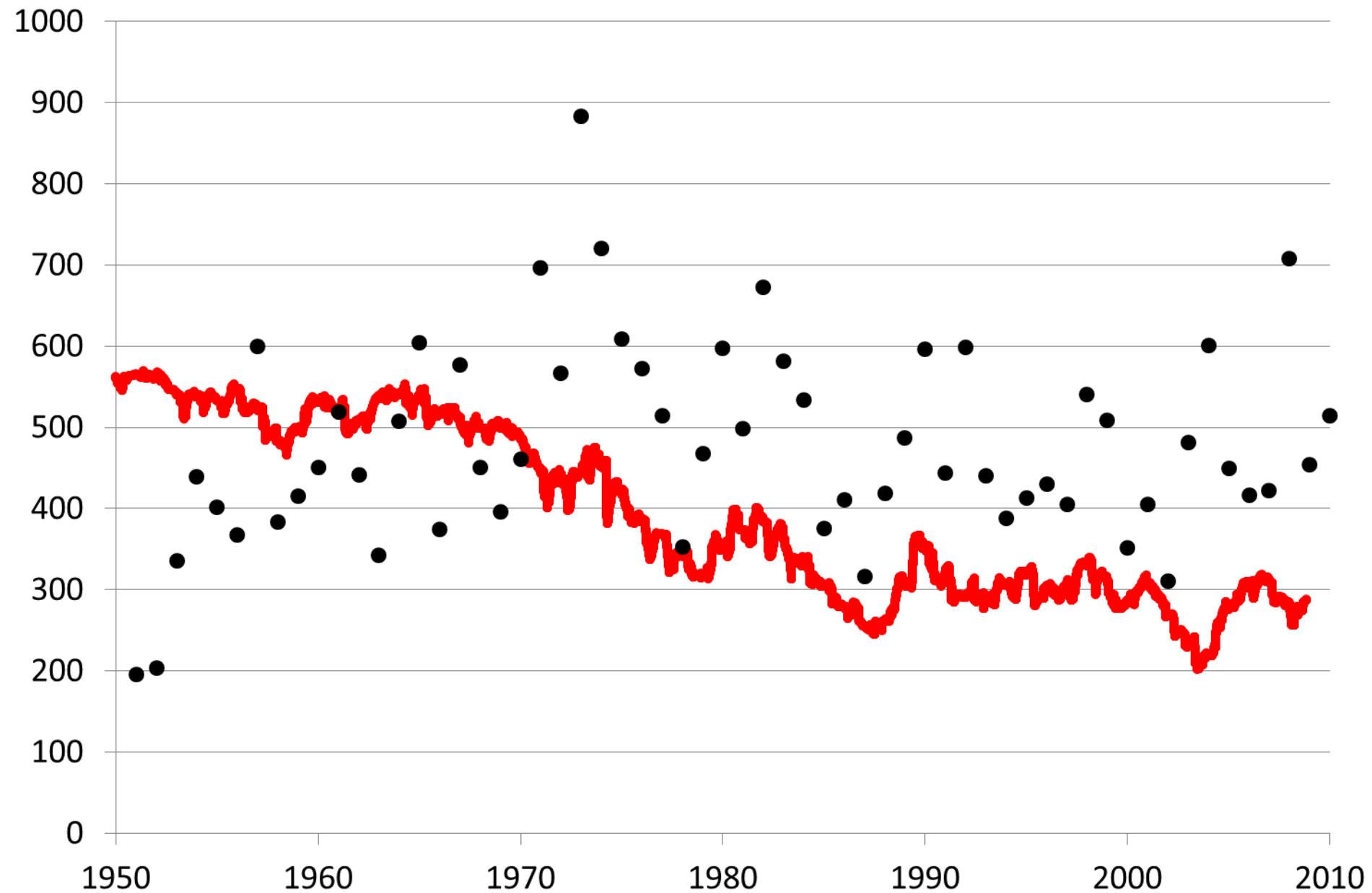
**Or better yet use  
F2-F5 since they  
Produce most damage**



# F1+ Tornadoes Per Year (Black Dots)

F2+ per 1000 F1+ (Red)

Harold Brooks NSSL

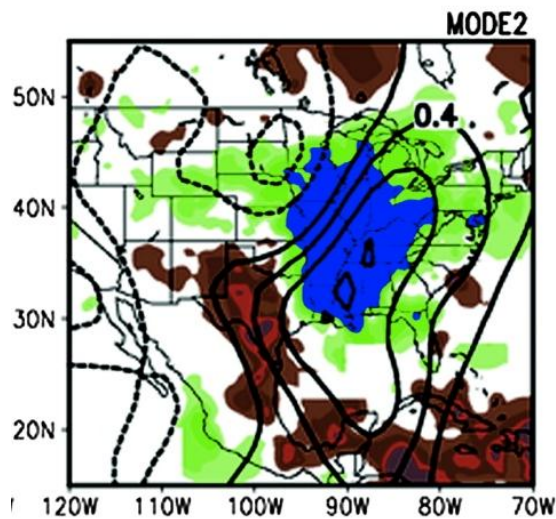
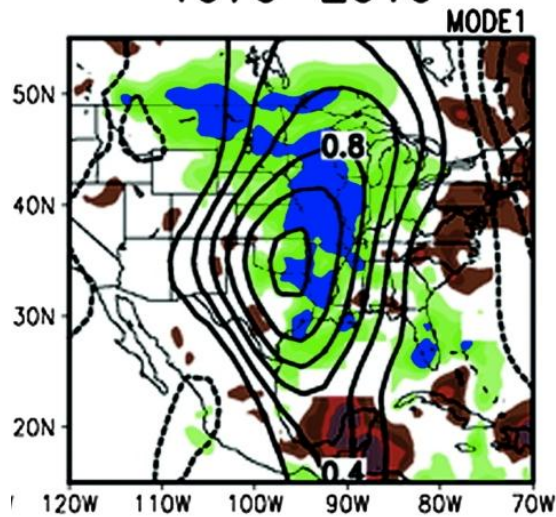


# Proxies

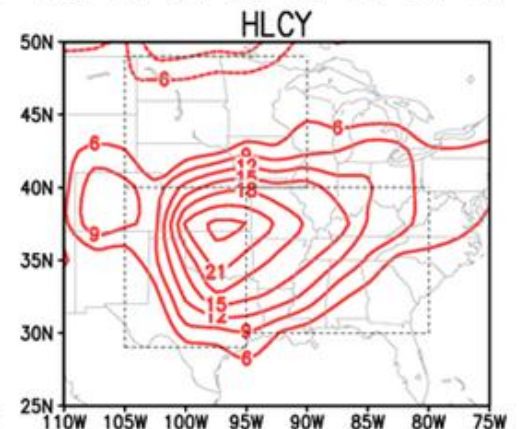
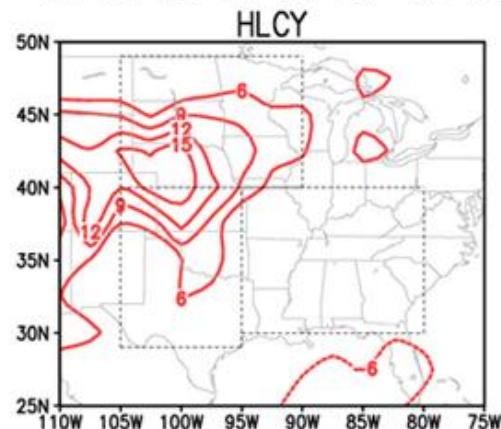
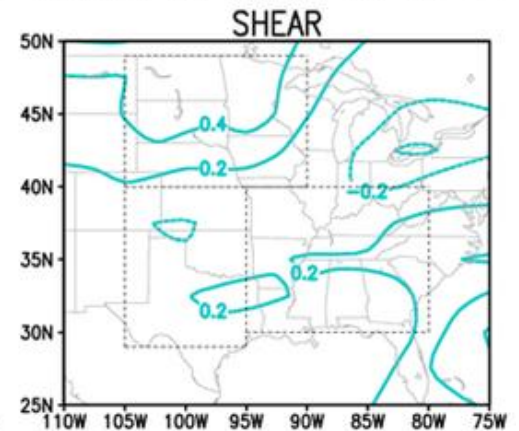
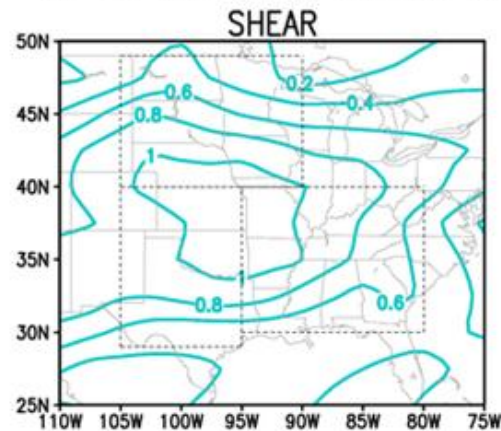
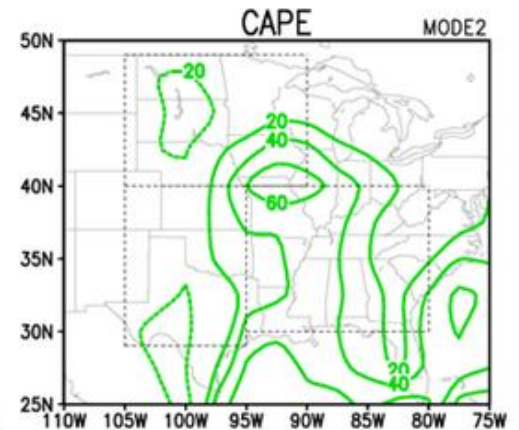
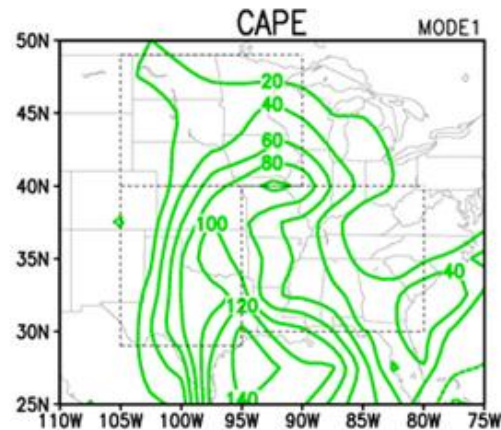


# AMJ NALLJ Variability Modes

1979–2010

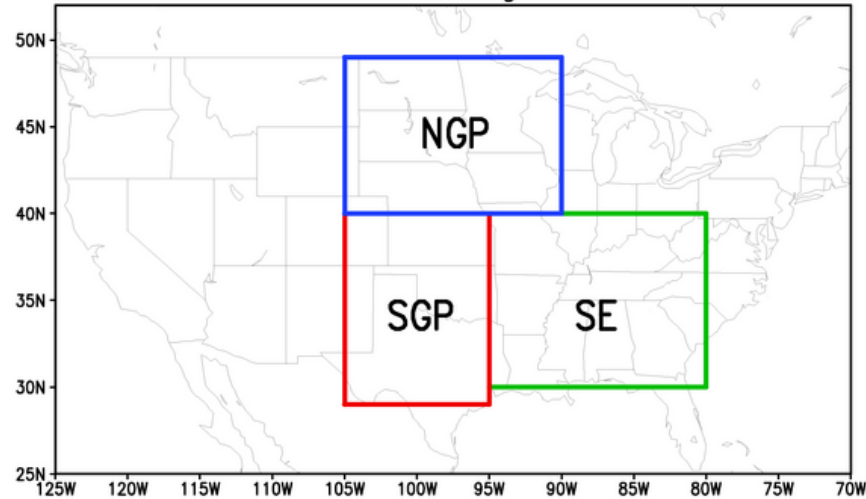


Scott Weaver CPC



# Combined Influence of NALLJ Modes 1 & 2 On Regional Tornadic Activity

Tornado Regions



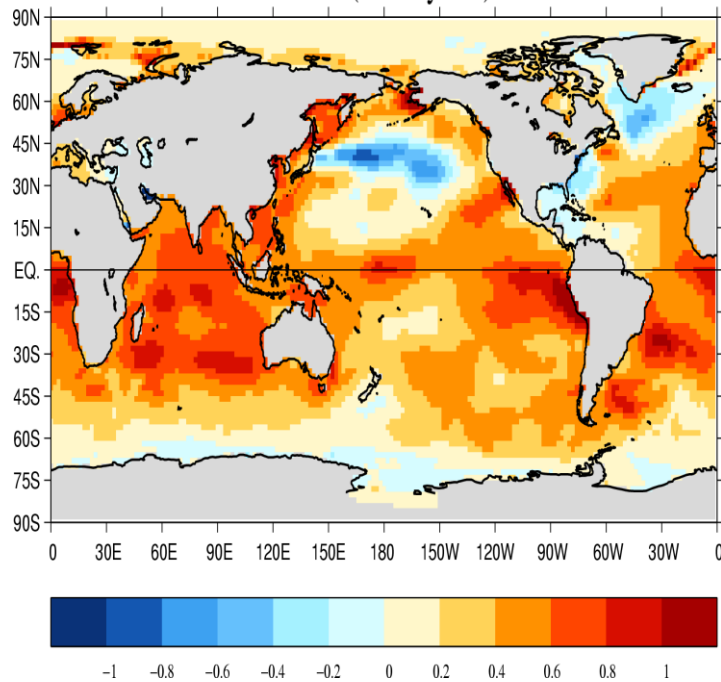
Seasons where both PC1 & PC2 are both Positive (Negative) and Tornado anomaly is also Positive (Negative)	PC1 & PC2 Positive	PC1 & PC2 Negative
At least one Region	14/18 + 78%	13/13 - 100%
All Regions	4/18 + 22%	9/13 - 69%

# Regional Tornadic Variability & Sea Surface Temperatures (SST)

- SST linkages offer prediction opportunity.
- Compare and contrast the spatial patterns of global SST variability to regional tornado indices.
- Strategy exhibits no a priori assumption regarding the structure of associated SST variability, the case and limitation when targeting connectivity to indices of ENSO.
- Northern Great Plains & SE example.

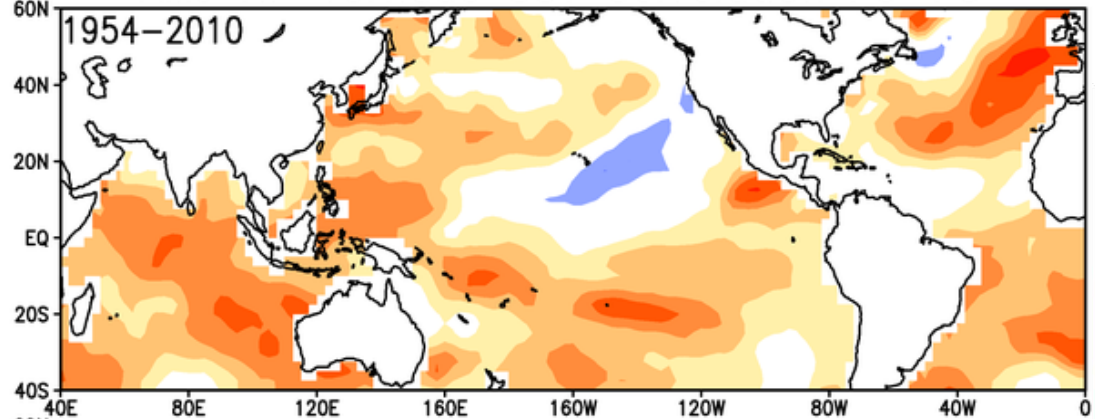


ERSST SST trend (C/50-years) 1950-2004

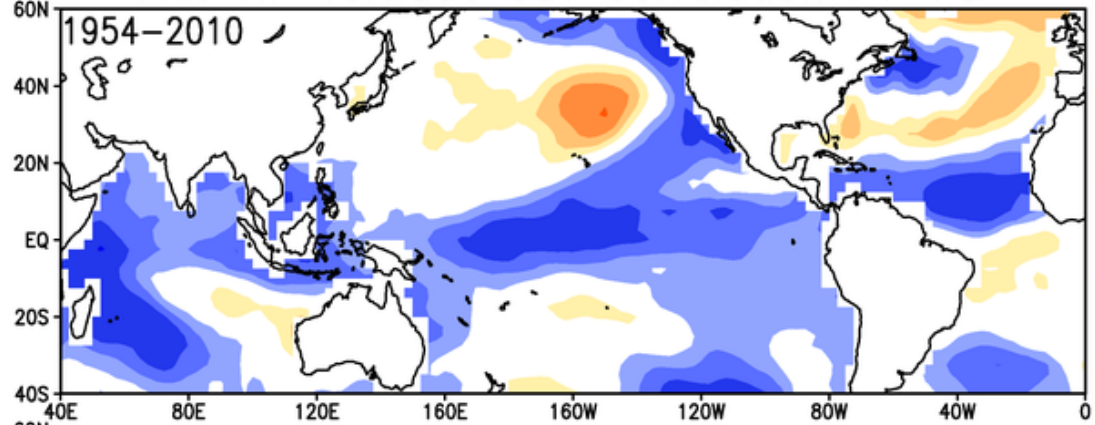


SST warming trend *coincident* with an increase in weak tornadoes at the expense of the stronger ones.

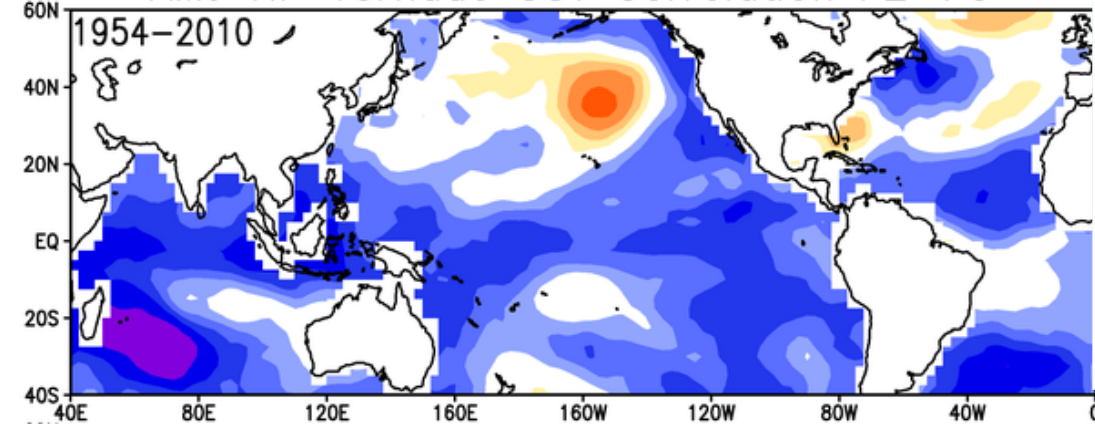
AMJ NP Tornado SST Correlation F0-F5



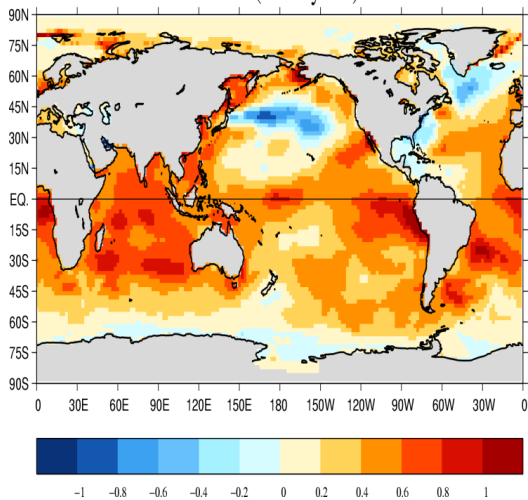
AMJ NP Tornado SST Correlation F1-F5



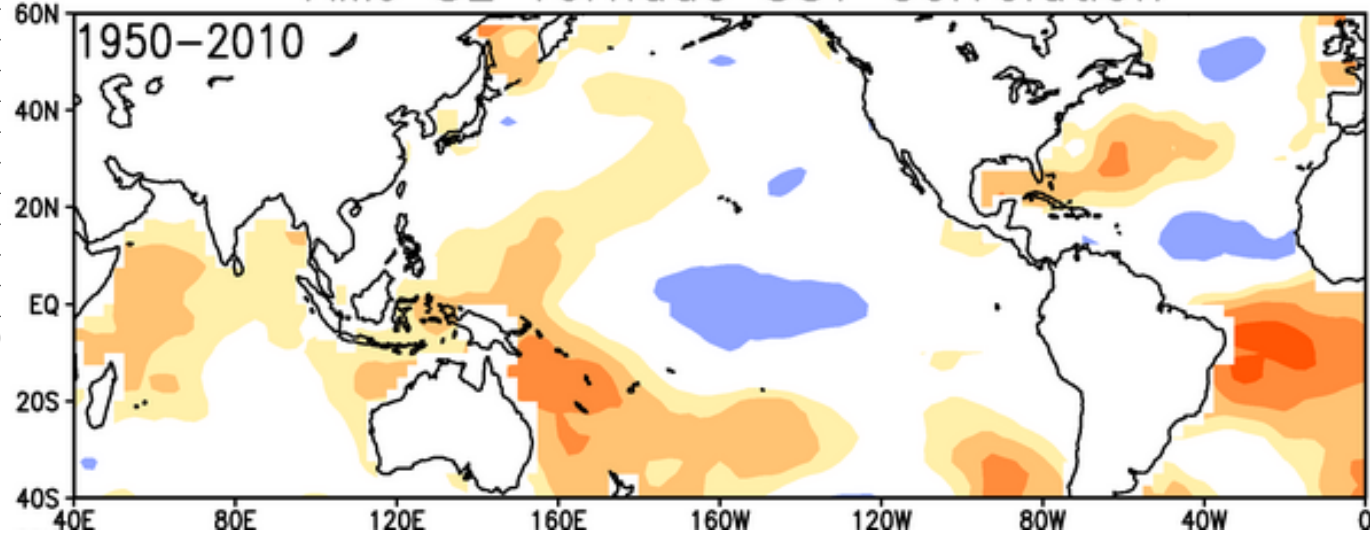
AMJ NP Tornado SST Correlation F2-F5



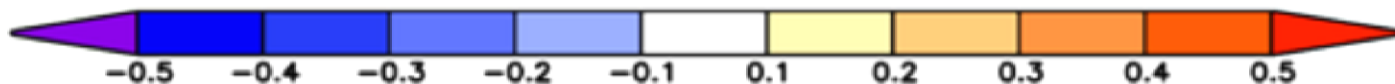
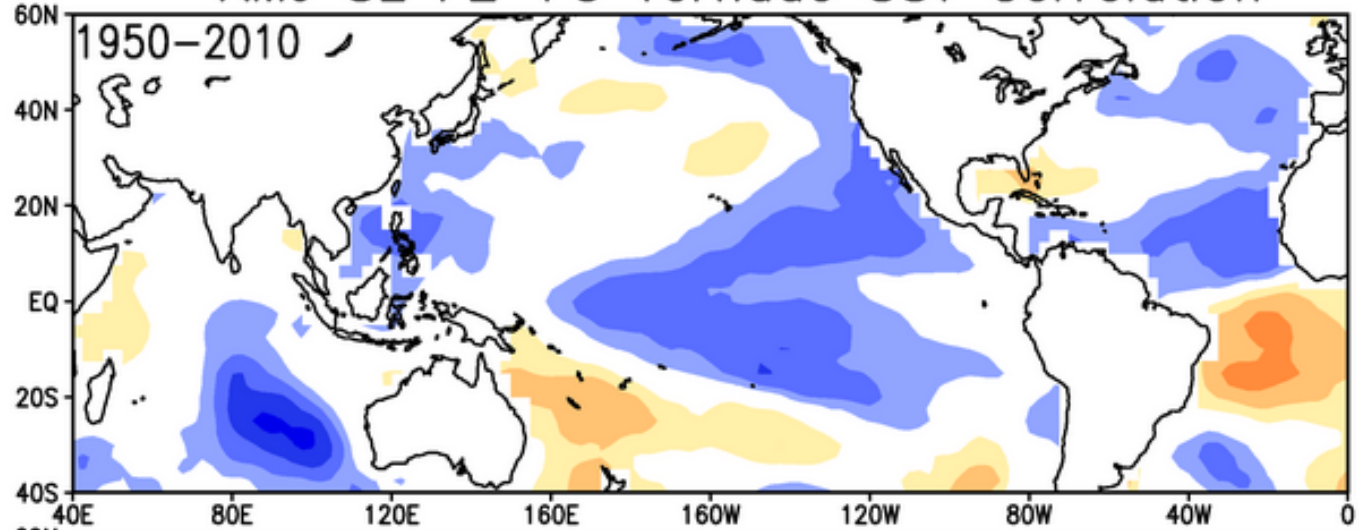
ERSST SST trend (C/50-years) 1950-2004



**F0-F5** AMJ SE Tornado SST Correlation

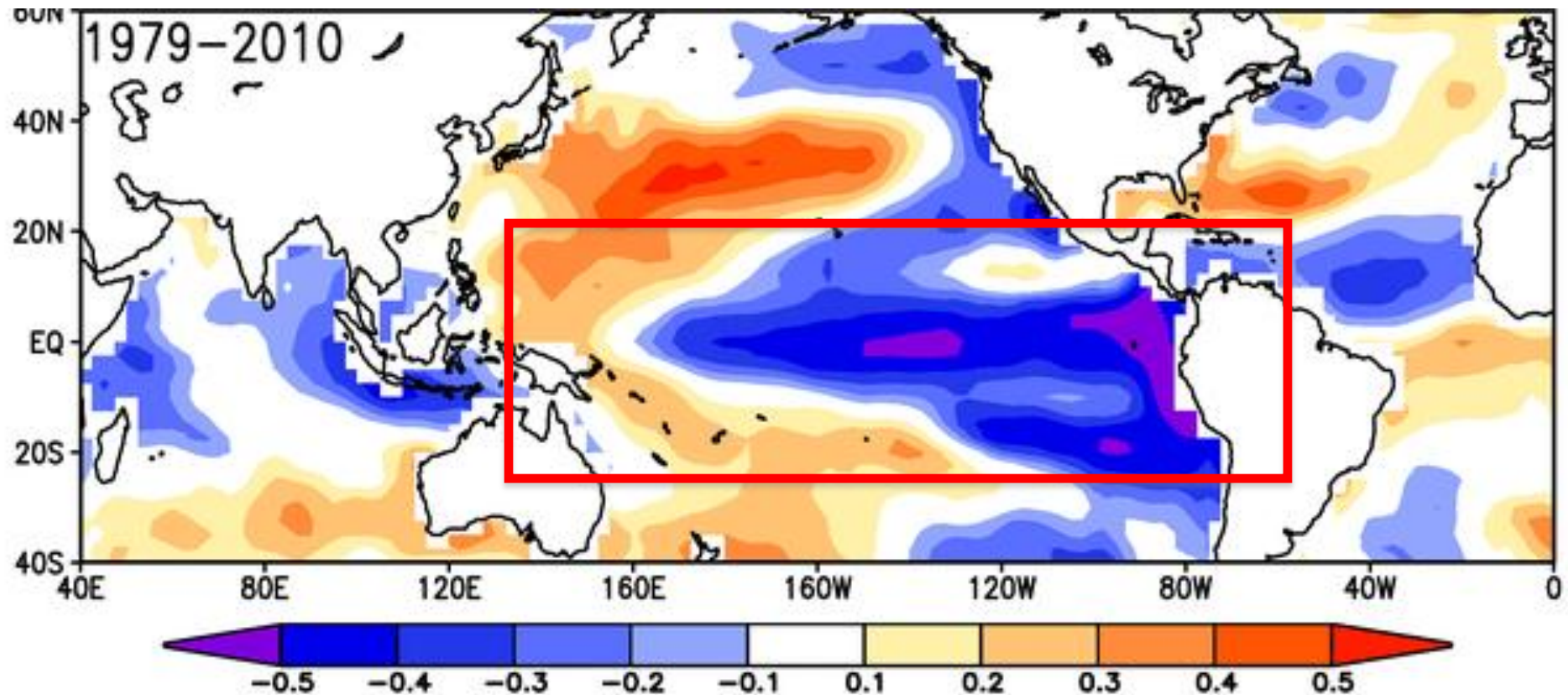


**F2-F5** AMJ SE F2-F5 Tornado SST Correlation



If the trend is artificial  
why is the SE U.S.  
somewhat immune ?

# AMJ NP DAYS Tornado SST Correlation



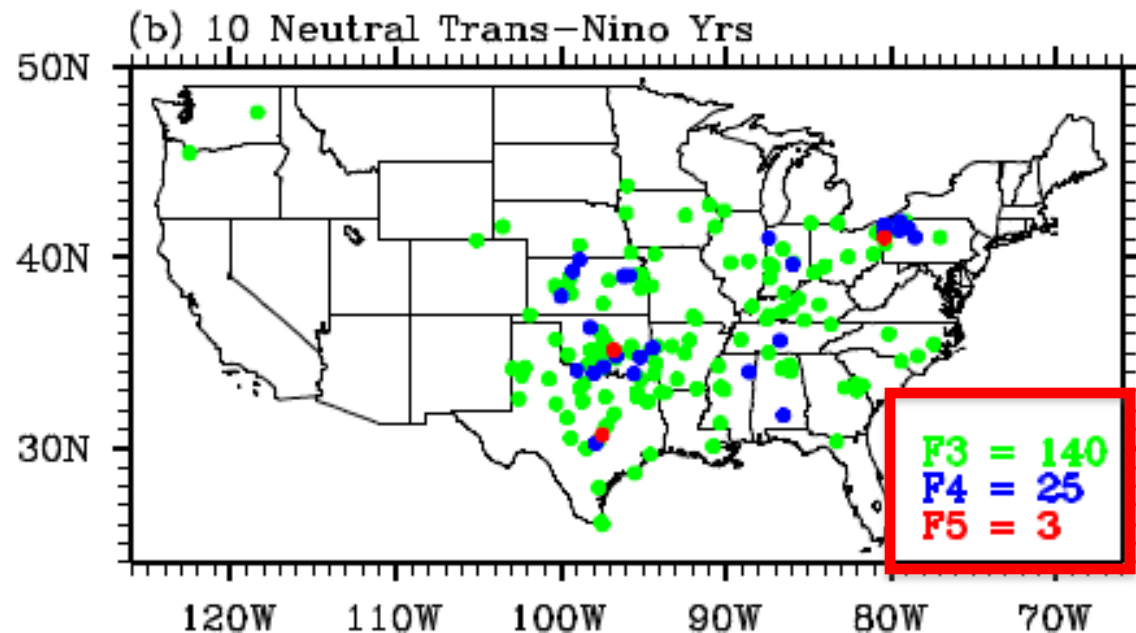
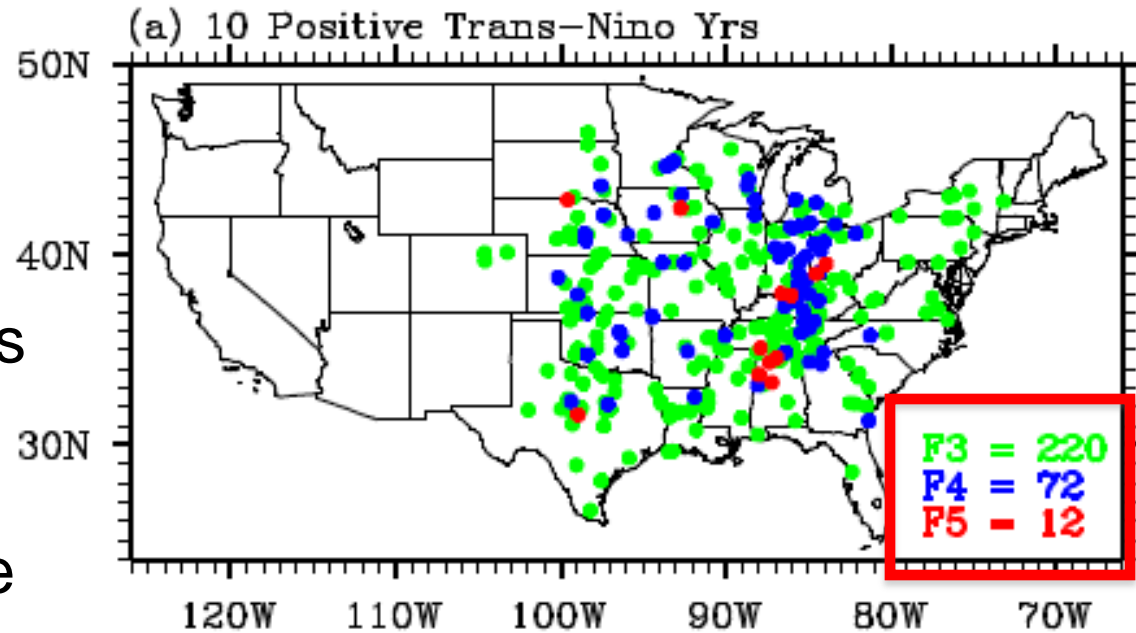


SWD: Incidents of Intense (F3–F5) U.S. Tornadoes  
during 1950–2010 (APR–MAY)

Trans Nino Index (TNI)  
[Nino1+2] – [Nino4]

Modeling study indicates  
That positive TNI  
enhances MFC from  
GOM via changes to the  
GPLLJ

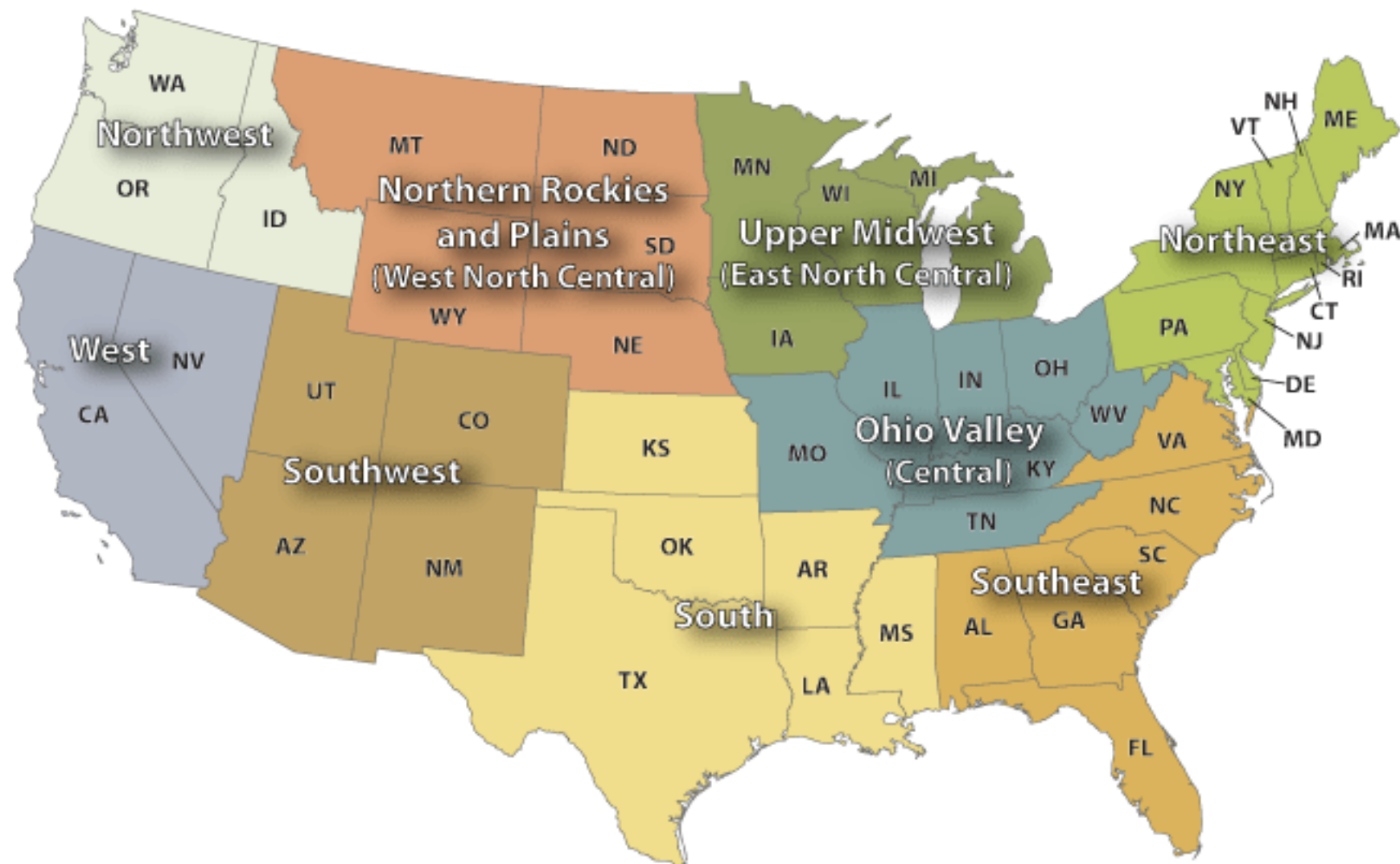
Sang-Ki Lee AOML



# A Prediction Example



## U.S. Climate Regions



# Tornado Index Regional correlations

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
South	0.16	0.36	0.29	0.05	0.28	<b>0.51</b>	0.09	0.34	0.05	0.30	0.29	0.33
Southeast	0.22	0.24	0.00	<b>0.41</b>	<b>0.66</b>	0.25	-0.01	0.00	<b>0.49</b>	0.26	<b>0.45</b>	<b>0.47</b>
Central	<b>0.47</b>	<b>0.50</b>	<b>0.64</b>	0.23	0.37	<b>0.45</b>	<b>0.42</b>	0.05	0.19	0.03	0.24	<b>0.42</b>
Midwest			-0.12	<b>0.58</b>	0.15	<b>0.67</b>	<b>0.39</b>	<b>0.42</b>	0.02	0.39	-0.04	
Plains			0.12	0.37	<b>0.40</b>	<b>0.50</b>	<b>0.53</b>	0.27	-0.03	0.03		
Northeast				0.15	0.05	0.15	<b>0.41</b>	0.18	0.70	0.15	-0.02	
Southwest				0.02	-0.10	0.32	0.04	-0.01	-0.44	0.30		
Northwest				-0.14	0.15	0.30		0.19				
West		0.21	0.34	0.13								

TABLE 4. Correlation between the index and reported number of tornadoes by U.S. climate region and month for the period 1979-2010. Significant correlations are in bold font. Regions and months with less than 32 reported tornadoes are omitted.

Mike Tipett, IRI, 2013

# A Final Word

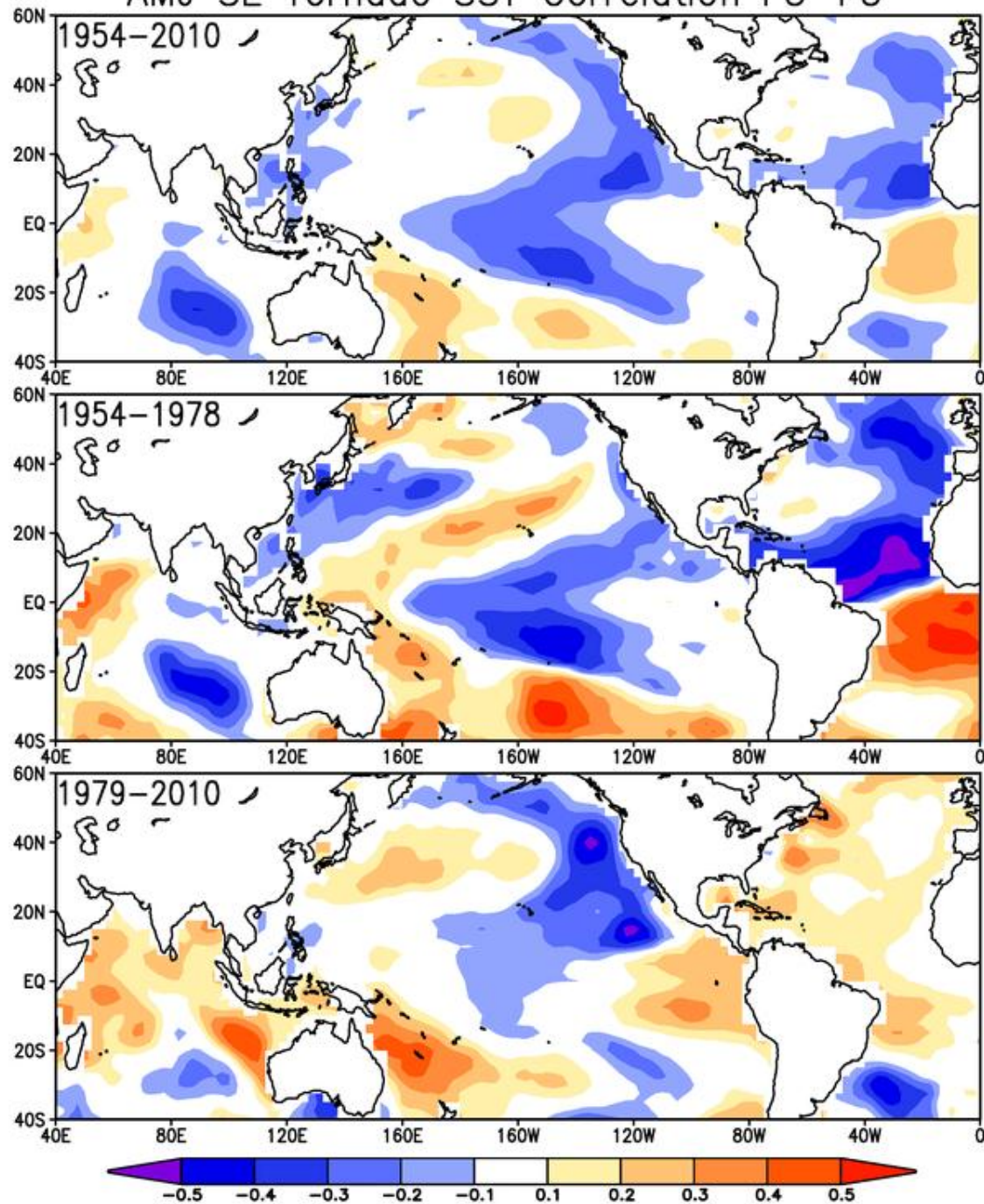
These are just a few vignettes. Other research includes:

- Downscaling methodologies.
- Intraseasonal variability. Some links to MJO in spring.
- New ways to correct the historical database.
- Exploiting modern technology to develop and maintain a new robust tornado database for the next generation of scientists.
- White Paper available upon request.

Questions?

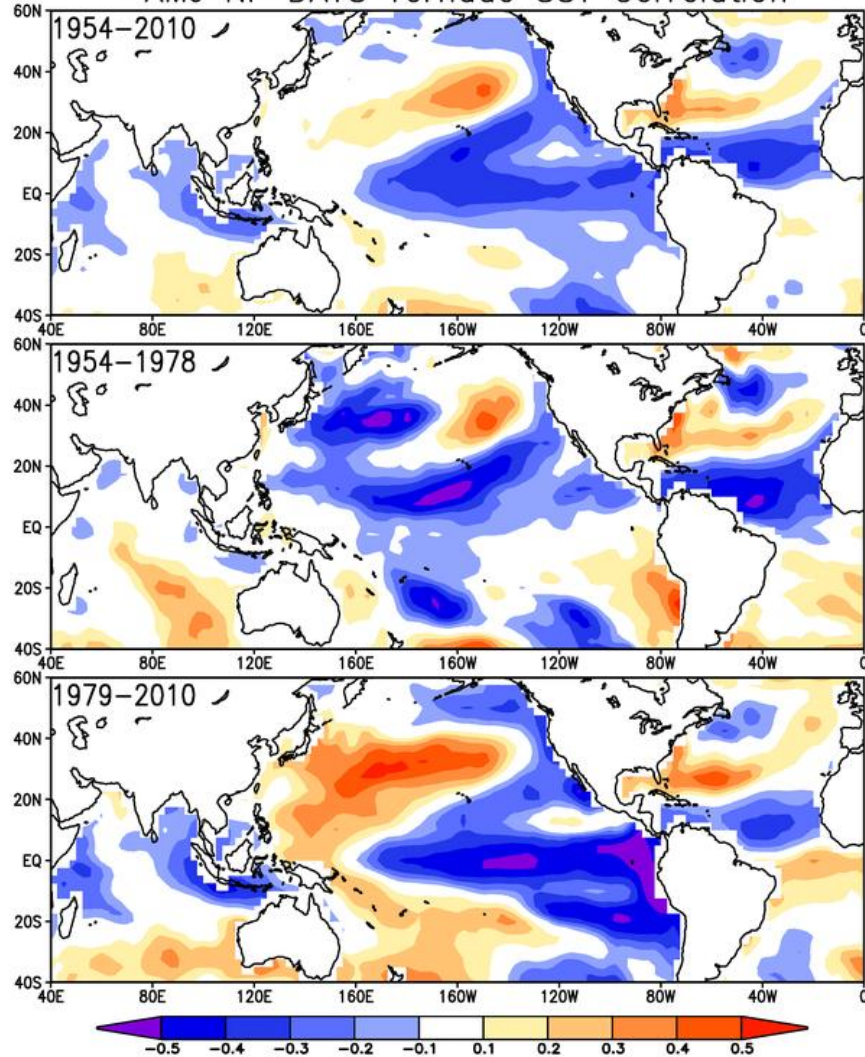
[scott.weaver@noaa.gov](mailto:scott.weaver@noaa.gov)

# AMJ SE Tornado SST Correlation F3-F5

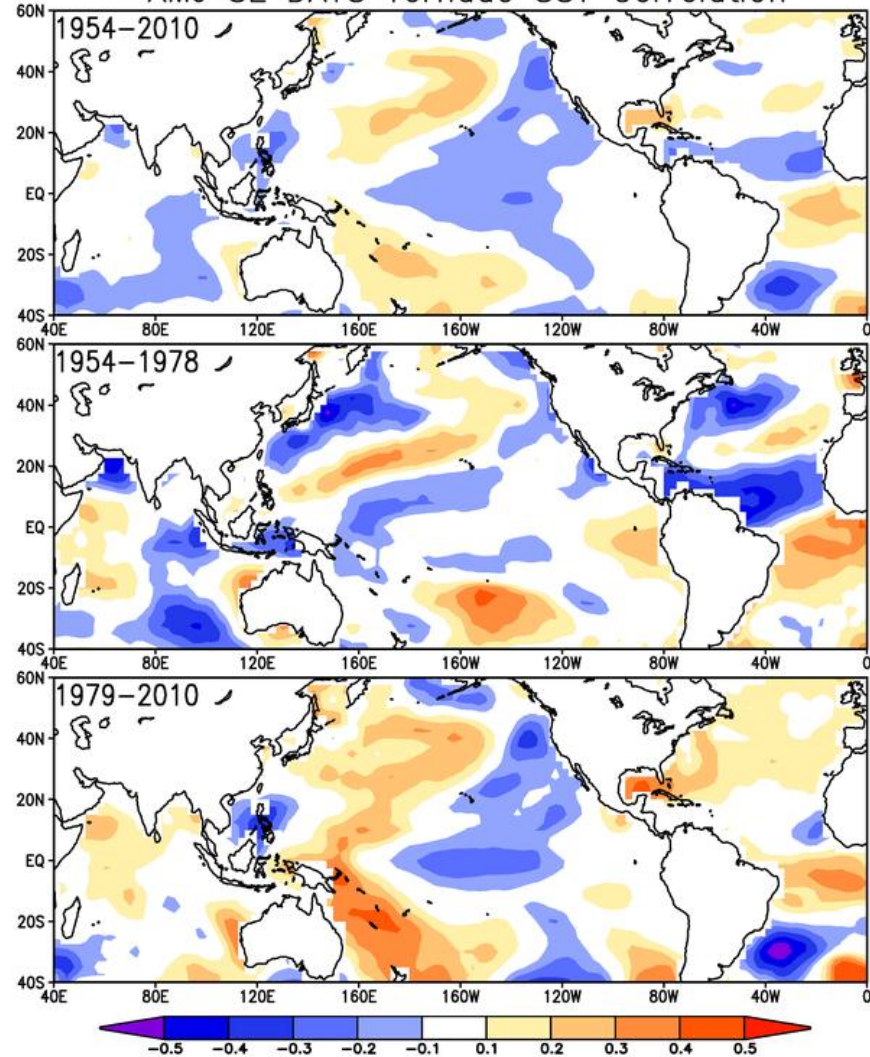




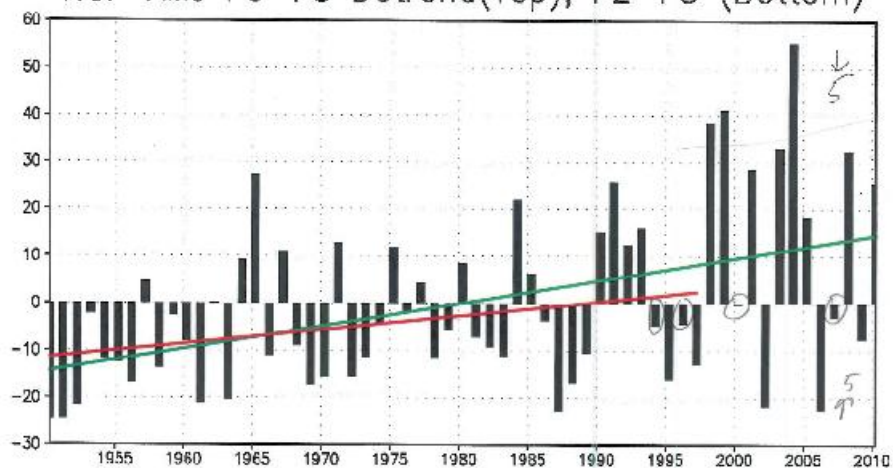
AMJ NP DAYS Tornado SST Correlation



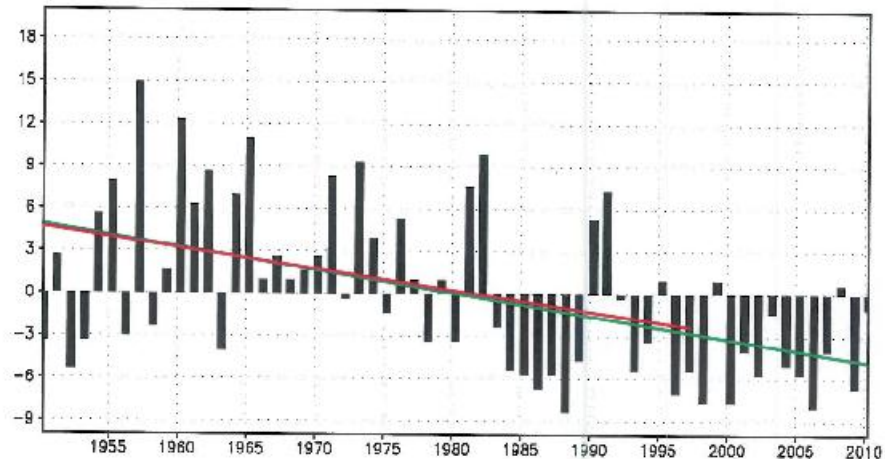
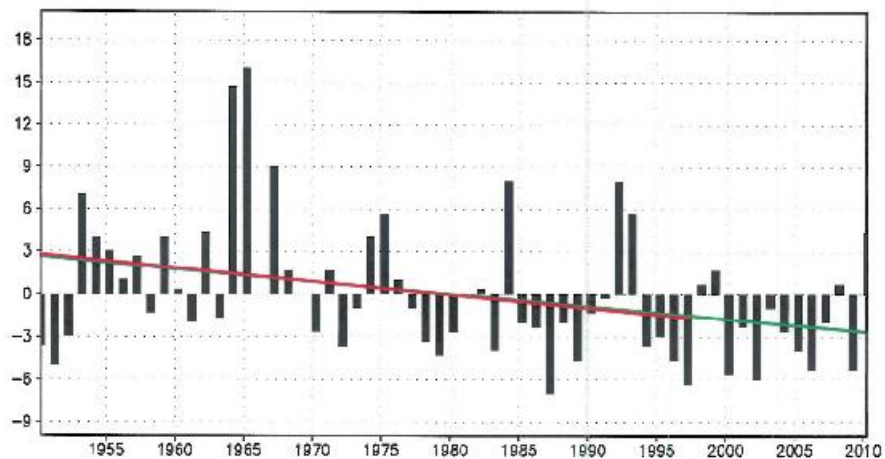
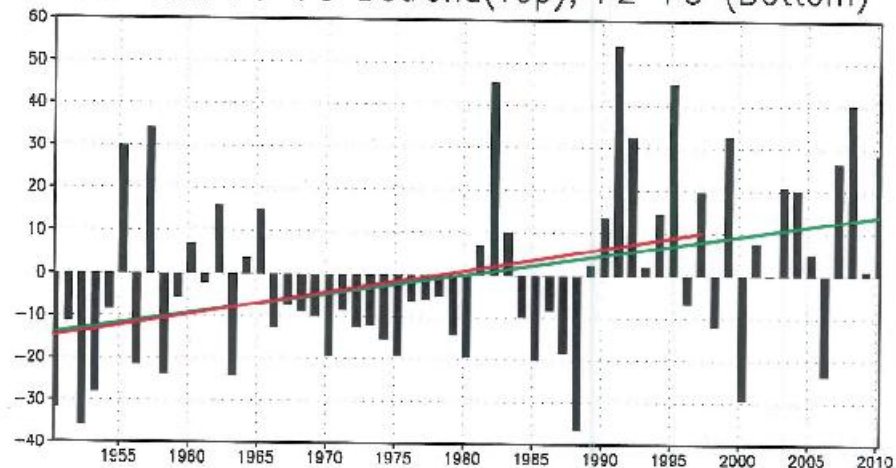
AMJ SE DAYS Tornado SST Correlation



NGP AMJ F0-F5 Detrend(Top); F2-F5 (Bottom)



SGP AMJ F0-F5 Detrend(Top); F2-F5 (Bottom)



SE AMJ F0-F5 Detrend(Top); F2-F5 (Bottom)

